Satellite Communications for Air Traffic Management

Mohammed A. Shamma

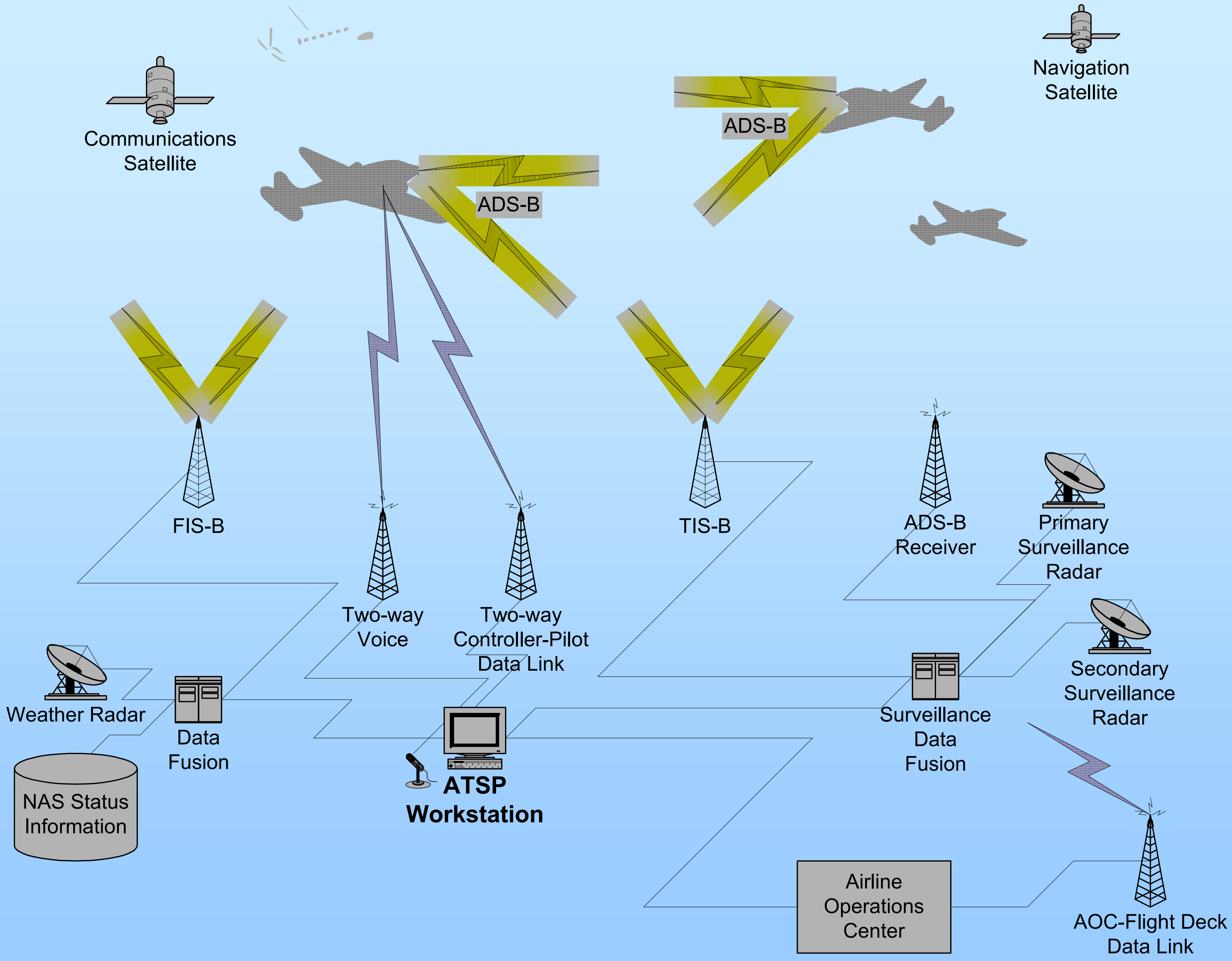
Project

- The work here was done as part of the Advanced Communications for **Air Traffic Management Project at NASA Glenn Research Center in Cleveland, Ohio**

Satellite Communications for Air Traffic Management

- High light roles Aeronautical Mobile Satellite Service, AMSS and Next Generation Satellite Service NGSS can play within Air Traffic Management ATM
- Investigate different architectures that involve satellite system:
  - Use SatCom as a primary
  - Use SatCom as an integral sub-component
  - Use SatCom as a backup
- Highlight benefits and disadvantages by comparing full systems (primary) vs. partial (sub-component)

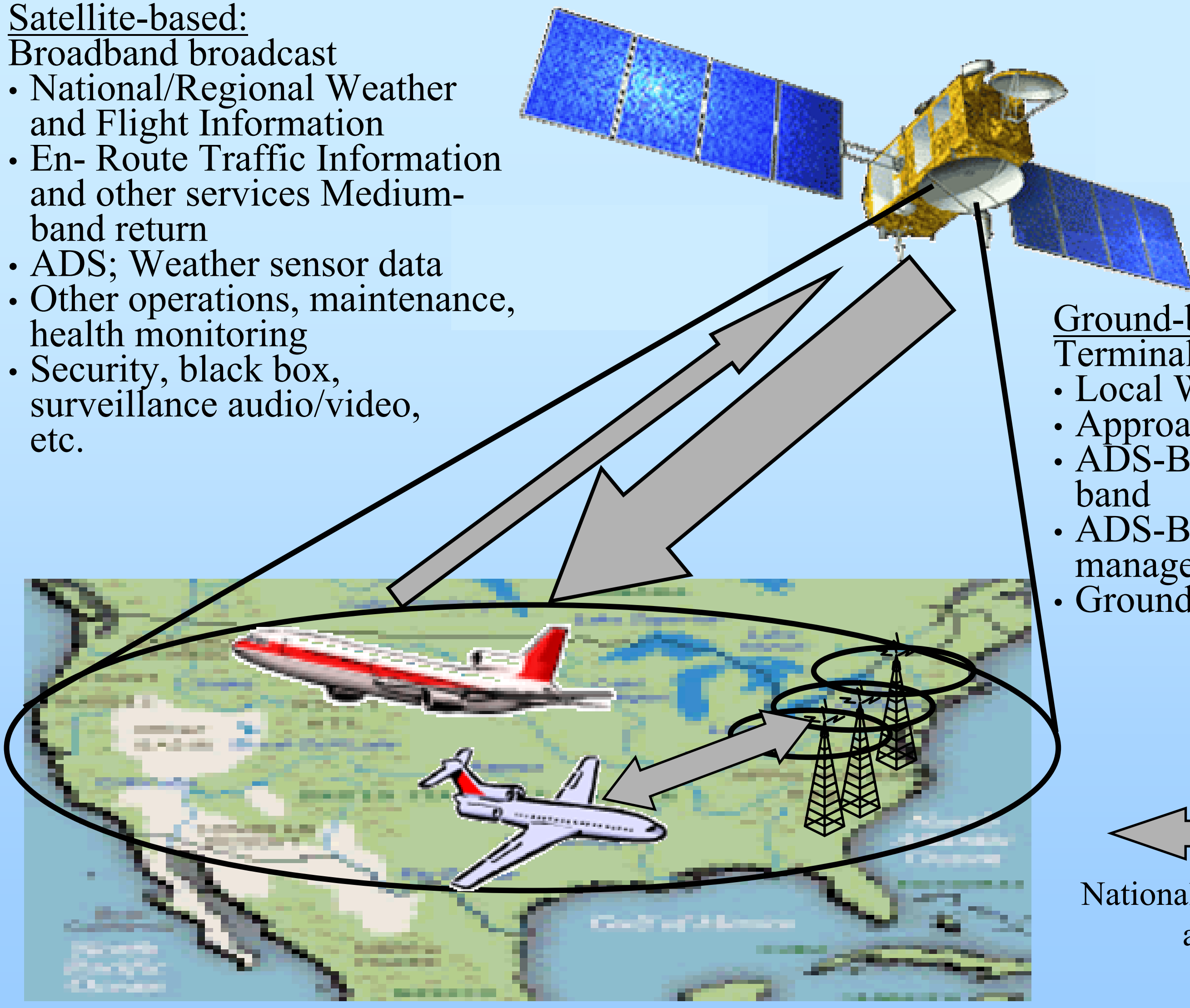
Future ATM Components



Future Satellite Subnetwork

<u>Satellite-based:</u>
Broadband broadcast

- National/Regional Weather and Flight Information
- En- Route Traffic Information and other services Medium-band return
- ADS; Weather sensor data
- Other operations, maintenance, health monitoring
- Security, black box, surveillance audio/video, etc.



<u>Ground-based:</u>
Terminal area broadband:

- Local Wx, FIS, TIS
- Approach/departure
- ADS-B Surface medium-band
- ADS-B round traffic management
- Ground ops clearances, etc.

National/Global Interoperbility and Networking

Prior to ATM Proposals

- Sat Communication Usage was very limited
- Mainly provided by Inmarsat Services since the 1980s Aero-H, H+, L (still Current AMSS Standard)
- ACARS provided Data services over satellite links (as well as HF and VHF)
- Systems were not heavily used due to experimental status and costs

ATM Proposals

- ATM proposal/standards by ICAO, ITU, RTCA fall into two categories:
  - Aeronautical Mobile Satellite (Route) Service (AMS(R)S) based on Annex 10, Vol. 3, part 1, chapter 4 standards
  - Next Generation Satellite Services (NGSS) based on AMCP/WGA-WP/666b

AMS(R)S

- AMS(R)S is based on the Inmarsat Service already operational
- Technology is based on:
  - Geo Satellites (4 of them)
  - L band 1550-1630.5 Mhz
  - TDMA channels packet data up to 10500 b/s (P channel ground to air), (T channel air to ground user data)
  - Circuit Switched (C channels) for voice, data, both ways
  - Random Access channel R for air to ground data requests

NGSS

- NGSS attempts to include newer technologies that have developed since AMSS SARPS were put in place
- Uses GEO, MEO, or LEOs
- Satellite access, and link is not fixed to the Inmarsat based AMSS
- Several Systems fall within it:
  - Boeing (16 LEOs, CDMA access, uplink/downlink)
  - SDLS (Europes NGSS, GEO based with CDMA access)
  - Other systems that were initially geared to non aeronautical services (Iridium, Globalstar, Teledesic, ICO, Ellipso, CELESAT, Orbcomm,..)

AMSS vs. NGSS

AMSS

- AMSS technology already exist, well tested
- AMSS based on what is considered older technology
- AMSS standards are well documented and established
- AMSS costs are still high and usage is limited to oceanic regions

NGSS

- NGSS does not exist, technologies still in development stage
- NGSS can utilize current technologies that are better
- NGSS standards are not well established
- NGSS costs are most likely high in the near future

Satellite Roles

- Full Usage
  - It can be a primary service providing uplink and downlink capability to all aircraft nodes. That includes ADS-B, CPDLC, TIS-B, FIS-B, and voice
- Sub-component usage
  - It can be a sub-component of the over all system, such as for example in providing only part of the services (i.e. TIS-B or FIS-B broadcasting)
- Backup
  - It can be a back up system providing all the services found in the item above as a backup
- Other
  - It can be used for other services as well (or only for other services) such as for other sources of information related to weather, or traffic, or emergency type information such as flight black box information, or other. As such it will be a secondary type of service that is available per demand per user

Full Usage

- **Full usage** will require uplink and downlink capability from the Ground and Aircraft nodes.   One architecture studied (with link analyses performed) is as follows:

Air To Ground Link

- Estimated, that by the year 2020, the busiest ARTCC might be required to handle a peak load of 600 aircraft.
- ADS-broadcast specification, assuming the maximum state vector update rate of one second, can be estimated to be 423 bits per second
- Average data rate for CPDLC-like ATC messaging is estimated at 153 bps
- CDMA uplink from each aircraft using the sum of the two
- Requirements above with margin give 1 kbps channel to 9000 aircrafts using only 4- 27 Mhz satellite transponders.

Full Usage (continued)

Ground to Air

- Communications load for the ground-to-air link consists of the CPDLC messaging to the aircraft and the TIS and FIS broadcast.
- CPDLC data rate is equivalent to the air-to-ground rate. The CPDLC messaging at peak load would require 1.38 Mbps
- TIS-B specifications are currently being developed. Upper limit of all of the combined ADS-B messages was assumed, it would require, for the system peak load case, 3.81 Mbps.
- High-resolution graphical weather data may become a standard part of FIS in the future, requiring several Mbytes or more to be transmitted, updates of weather information are infrequent, ranging from 15 minutes to several hours. Hence, average data rates required for en-route FIS will likely not exceed 50-100 kbps
- Combined total ground-to-air link requirement is 5.29 Mbps. This can be done using one 27 Mhz satellite transponder

Sub-Component Usage “Broadcast Systems”

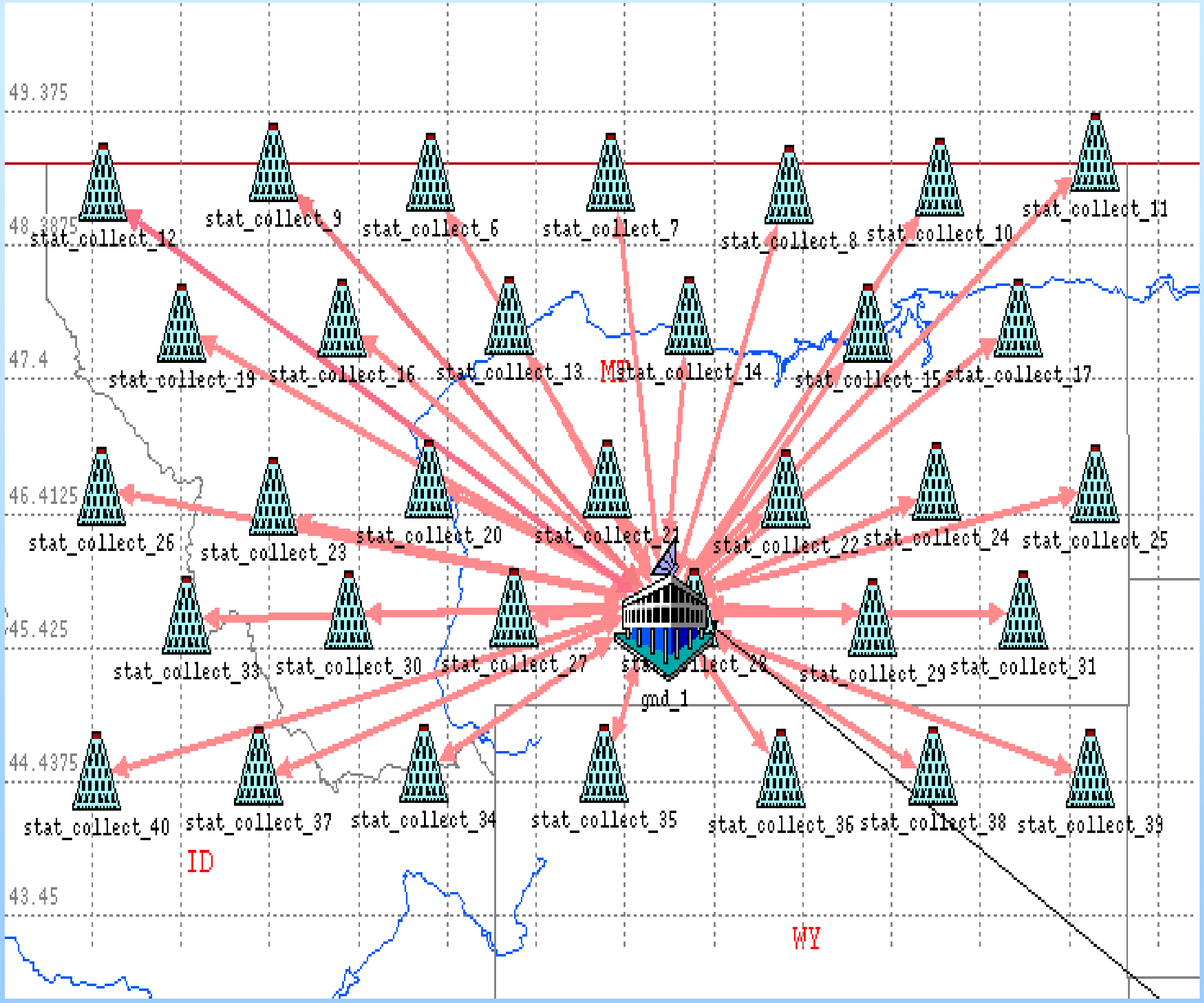
The satellite sub-Network can be used to broadcast TIS-B and FIS-B messages which would work as follows:

- Satellite ground stations used to transmit TIS-B and FIS-B messages collected from all the ADS-B and radar ground transceivers.
- The satellite itself used to relay the satellite ground stations TIS-B and FIS-B messages to all the aircraft.
- Ground satellite stations can be collocated at ATCC (20 of them at present).
- The airplane will have Satellite equipment for reception only

Communication Links/Accessing

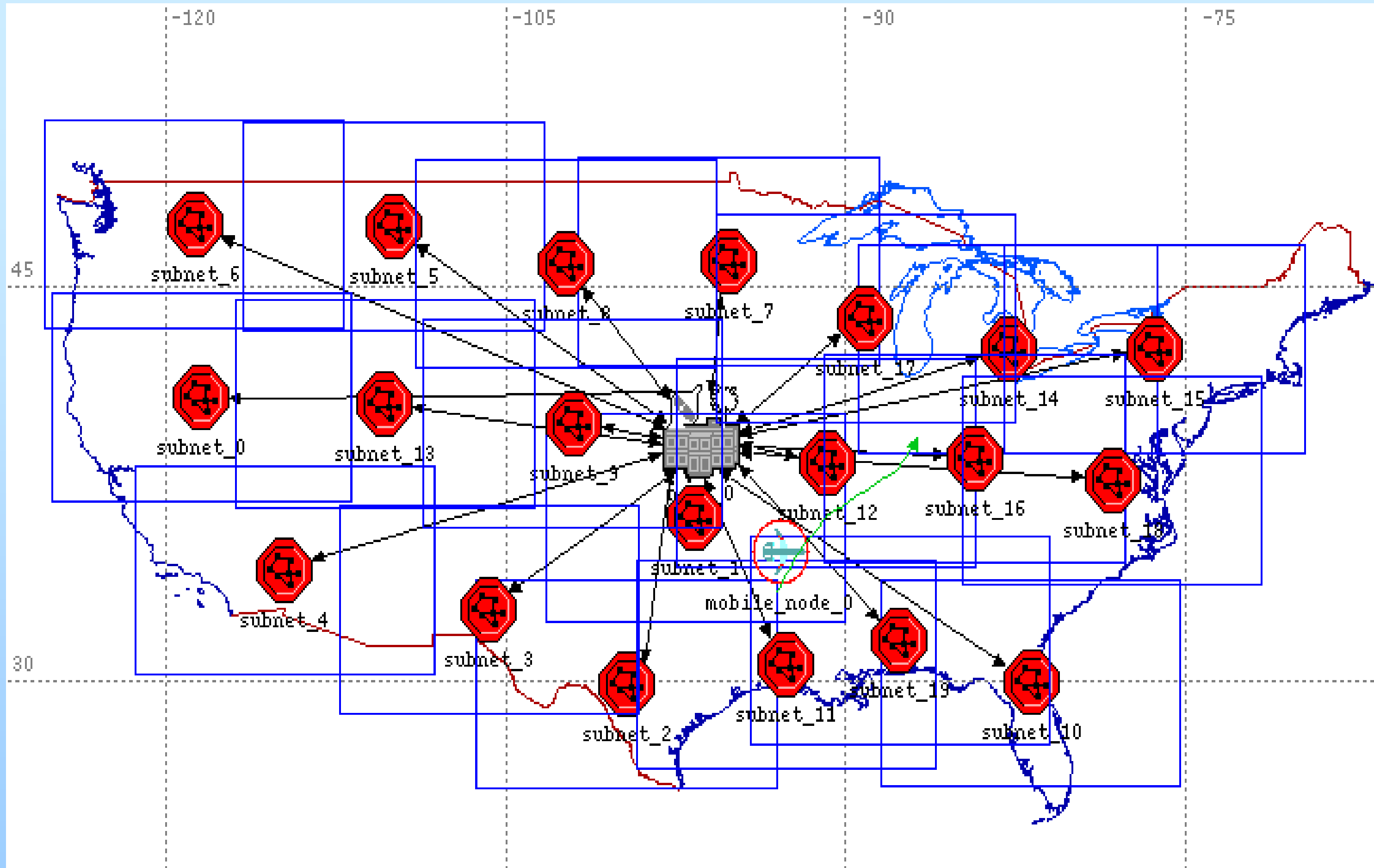
- One way of having all ground stations access the satellite is via TDMA.
- Airplanes satellite receivers can filter out regional data based on a pre-assigned TDMA sequence number. Pilots will have access to any TIS-B and FIS-B messages within the CONUS for forward planning
- One Satellite Transponder of 27 Mhz bandwidth should suffice (note analyses done with higher ADS-B packet sizes needed up to 2 - 27 Mhz transponders)

Sub-Component Usage Broadcast Systems (continued)



Surveillance Ground Subnetwork

Sub-Component Usage
Broadcast Systems (continued)



CONUS Satellite sub-Network (note that each node above corresponds to a sector with a satellite earth station and ADS-B ground stations as shown by Figure on previous slide. The satellite node is not shown).

Full vs. Subcomponent Usage

Full Uplink/Downlink

- Requires Transceivers onboard AES
- Higher Cost
- Requires higher gain antennas
- Needs more BW for uplink
- Needs new Technologies, and sharing is a problem for AES with other ground Mobile users
- Capable of many more applications (CPDLC, ADS-B, Voice)
- Examples: Boeing, SDLS
- Difficult to Implement
- Relies less on Ground based services already existing. Hence will not complement VDL-3 migration
- Unrealistic to transition backwards to a subcomponent usage

Partial (broadcast)

- Requires only receivers onboard AES
- Lower Cost
- Only for receiving, hence lower gain antennas
- No BW for uplink
- Can use existing technologies or satellite services (Sharing)
- Only TIS-B and FIS-B (no ADS-B, no voice, no CPDLC)
- Examples: Broadcasting Sats
- Easy to implement
- Relies on Ground based services as necessary means of transporting other services (ADS-B, CPDLC,..), Hence more likely to complement VDL 3 migration
- Can transition to Full System

Backup and Other Usages

- Can take many forms, i.e. architectures, systems, technologies
- Already exist as the Inmarsat for HF
- Can be utilized as a backup for Sat based systems (redundancy)
- Can compliment ground based networks for oceanic only, or remote areas that are not covered by VHF but covered by HF
- Can be used as back for links of various ATM processing centers
- Cost is still an issue for AES, but less than primary usage
- A minimum role that Satellite communication should take

Issues with Satellite Communications

- Good for high altitude Enroute service
- Not realistic for Terminal area (where higher density and Rain is a factor for any frequency band)
- Satellite antenna installation is costly for AES
- Delays for GEO for Voice applications
- Ideal for oceanic and no ground coverage areas
- Requires a high degree of reliability and redundancy is very important, but a costly issue
- Integration in sub-component implementations with ground based systems is an area that requires more research
- Ideal for solving capacity problems in VHF

Conclusions

- AMSS and NGSS can play a primary, secondary, or backup role within the ATM
- AMSS and NGSS can be implemented using existing technologies and in a cost effective way which could mean usage of existing satellite systems.
- Satellites are capable of broadcasting which is a key advantage
- NGSS can benefit not only from existing technologies but from future improvements in the antenna (phased array), spot beaming, satellite on board processing, and high capacity links in higher frequency bands such as in the Ka band